Advertising Entanglement Capabilities

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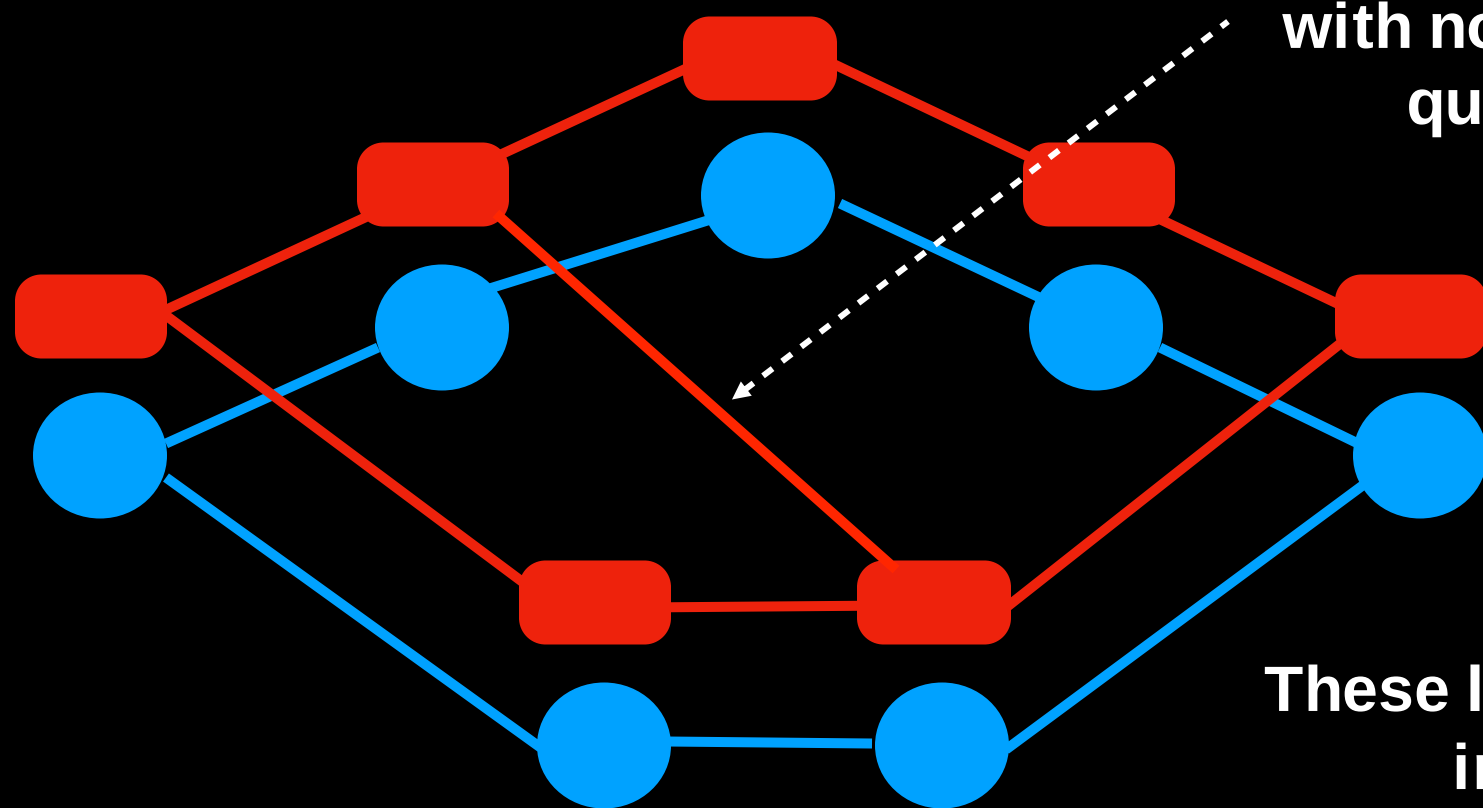
- Unusual outcome: not code, but an exploration of what it takes to create good entanglement pairs
- How this information can be shared across the quantum network to enable good “multihop entanglement”

Entanglement

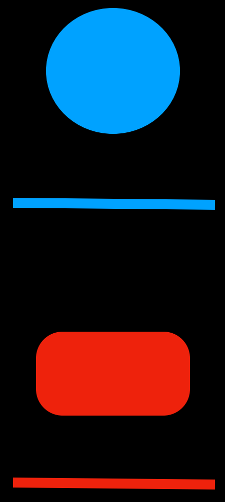
- A peculiarly quantum phenomenon
  - Leads to special networking features not available to classical networks
  - Entangled qubits are perfectly correlated; No one else can have any share of the entanglement.
    - Thus, they are private and correlated — perfect for QKD
- Creating “good” entanglement would thus be nice
  - What does “good” entanglement mean?
  - What do you need to make it?

Basics

There may be classical links with no corresponding quantum links



These links will be ignored in this context (they can be used for purely classical communications)



CQN

Quantum link

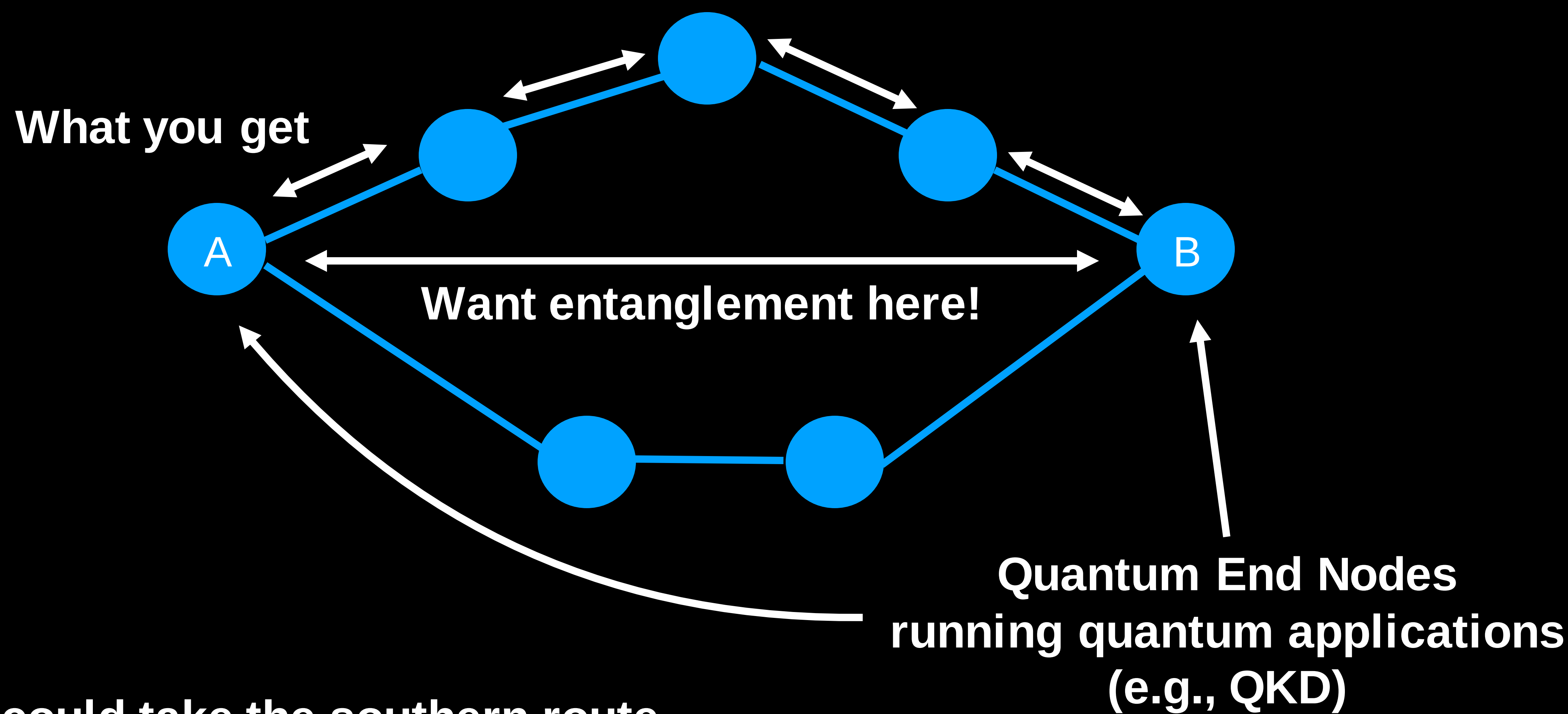
Classical (control) node

Classical link

Classical network parallels the quantum network

Classical nodes initiate quantum operations on the quantum nodes

Making Entanglement



Or you could take the southern route

Are they even more paths from A to B?

Which would be best?

What tradeoffs are available on each?

What’s needed to create multi-hop entanglement?

- What is the topology of the quantum network?
- What are the capabilities of each node?
  - # c-qubits, #s-qubits, operations?
- What are the capabilities of each quantum link?
  - How good an entanglement is the link capable of? how fast?
  - Can I distill to make the entanglement better?
- Can the “single-hop” entanglements across links be joined to a “multi-hop” entanglement between the QENs?
  - Does the multi-hop entanglement need distillation?

Proposal

- Run a link-state protocol on the classical nodes
  - Classical network topology = quantum topology
- Add entanglement capability TLVs to the link-state protocol
  - Each control node learns the entanglement capability of all nodes and links in the quantum network
  - With this information, it should be possible for each node to compute paths for multihop entanglement, probabilities of success, need for distillation, etc.

Properties Under Consideration

- Fidelity-time tradeoffs (link property)
- <u>Total</u> # c-qubits, # s-qubits (node property)
  - # of <u>available</u> qubits would be nice, but expensive
- Qubit operations possible (node prop)
- Distillation schemes possible (node prop)

Link-state vs. Shortest Path

- Van Meter et al[1] suggest using shortest path computation, using the inverse of (Bell pairs/s) at a given fidelity as link metric
- Our approach uses multiple metrics (node and link properties) and thus enables more complex algorithms
  - In the given example, the “southern” path has fewer hops, and thus (likely) a higher probability of successful entanglement
  - But the northern path may be capable of distillation, and thus could offer a better entanglement

[1] R. Van Meter, Satoh, T., Ladd, T., Munro, W., and Nemoto, K. Networking Science, December 2013, Volume 3, Issue 1-4, pp 82-95

Next Steps for draft

- Lots of work to do on the draft
  - Ensure it captures entanglement capabilities for multiple realizations of traveling qubits (currently focused on NV-center in diamond)
  - Feedback from folks working on ion trap, neutral atom and other realizations would be very welcome!
- Future draft with the detailed formats/encaps in LSR WG
- A short arXiv document planned for wider dissemination among QInt folks
- Prototype code for link-state advertisements?
- Lessons to be learned/extrapolation from QuTech’s proposed 2-hop entanglement experiments in the lab and in the wild

Next Steps in QIRG

- Does this fit in the QIRG charter?
- If so, how do the chairs want to proceed?
- Is the QIRG mailing list a good place to discuss?

Questions to the RG chairs